Opportunities in the Building Sector: Managing Climate Change

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Opportunities in the Building Sector: Managing Climate Change

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Abstract. We review the data documenting the value of energy efficiency measures enacted in California, largely in the buildings and appliance sectors. We compare energy savings in the state to those achieved in the US as a whole. We also compare the cost and energy savings possible with efficiency standards enacted in China with the cost and quantity of energy expected from the construction of the Three Gorges Dam there.

U.S. AND CALIFORNIA ENERGY SITUATIONS

Faced with increasing concentrations of atmospheric carbon dioxide, many countries are aggressively implementing measures to reduce these emissions. Although the United States has not yet committed to reducing its carbon dioxide emissions, the State of California is moving forward with its efforts to reduce carbon emissions to 1990 levels by the year 2020. The specifics of how California will proceed are under development. Full implementation is expected in 2012, with some earlier measures prior to that date. In this paper, we will provide an overview of energy consumption in the United States and in California with particular emphasis on efforts that California has made to increase the efficiency of its energy use. Also, we will discuss and describe cost curves for carbon reduction and contend that much of the reduction needed to modulate global warming could be achieved at negative costs.

In 1974, the California Energy Commission was formed to develop and implement the first energy efficiency standards for buildings and appliances in the United States as well as assess supply and demand conditions, and site new thermal power stations. Over the years, the Commission also has developed capabilities and funding for research and development (R&D) efforts related to energy and environmental issues. Currently, funding in the R&D area amounts to $80 million dollars per year with about half of this focused on energy efficiency and demand response.

A common measure of energy efficiency is energy intensity E/GDP**,** defined as the quantity of primary energy E consumed per unit of gross domestic product (GDP). Energy intensity in the United States has declined at five times the historical rate since the 1973-74 oil crisis raised, not only, the price of energy but, along with it, an awareness of energy consumption and an appreciation for energy efficiency.

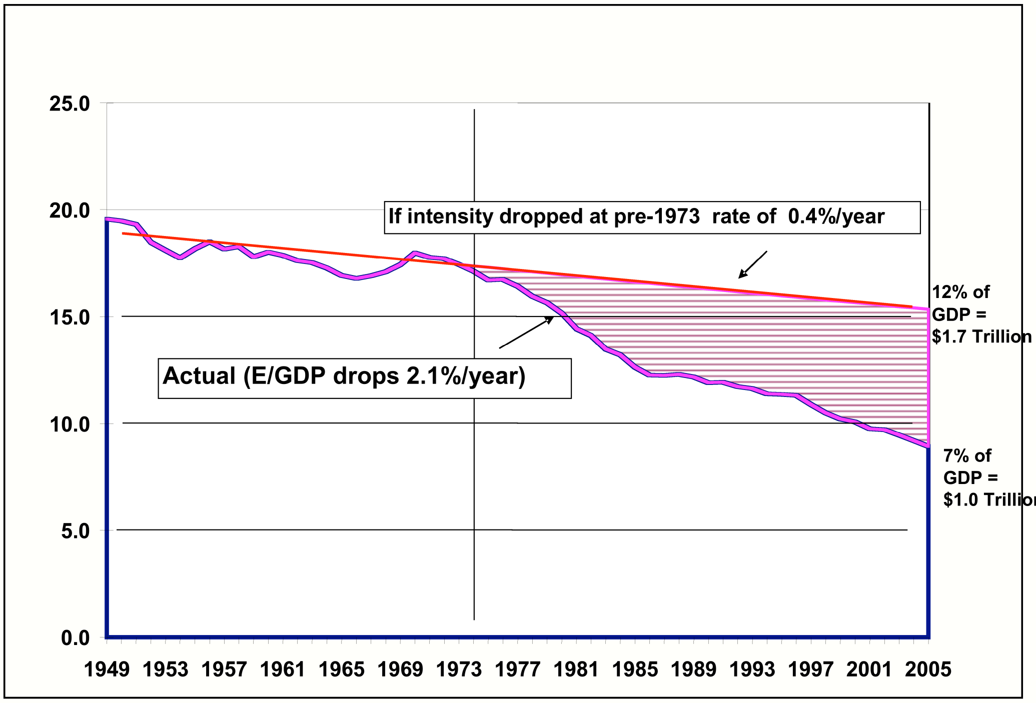

FIGURE 1. US energy Intensity in thousands of BTU per 2000-dollar per person from 1949 to 2005.

Figure 1 illustrates the decline in energy intensity in the US, especially since 1973. The impact of this improvement on primary energy demand is illustrated in Figure 2**.** If, instead of the actual 2.1 percent decline per year experienced since 1973, the United State's energy intensity had decreased by only the business-as-usual pre-1973 rate of 0.4 percent per year, energy use in the country would have risen by an additional 70 quadrillion Btus (quads) in 2005. Even with this improvement, primary energy use still climbed by 25 quads during these three decades. The monetary savings, associated with improvements in energy intensity in the US, amount to about $700 billion in 2005 as a result of reducing primary energy demand by about 70 quads, compared to what it could have been if pre-1973 energy intensity levels had remained unchanged through the subsequent three decades.

Improvements in energy intensity arise from many factors: improved technology, customers facing higher energy prices, consumer awareness and others. These improvements occur throughout the economy. We estimate that the $700 billion in foregone energy expenditures in the United States (in 2005 compared to what we would have spent if the energy intensity of the U.S. economy had improved at only 0.4% per year) was 1/3 due to major structural changes in the economy (less heavy industry and more high tech); 1/3 due to improvements in transportation (Corporate

Average Fuel Efficiency, or CAFE, standards); and 1/3 from improvements in buildings and industry (compact fluorescent light bulbs, better motors, building and appliance standards, etc.)

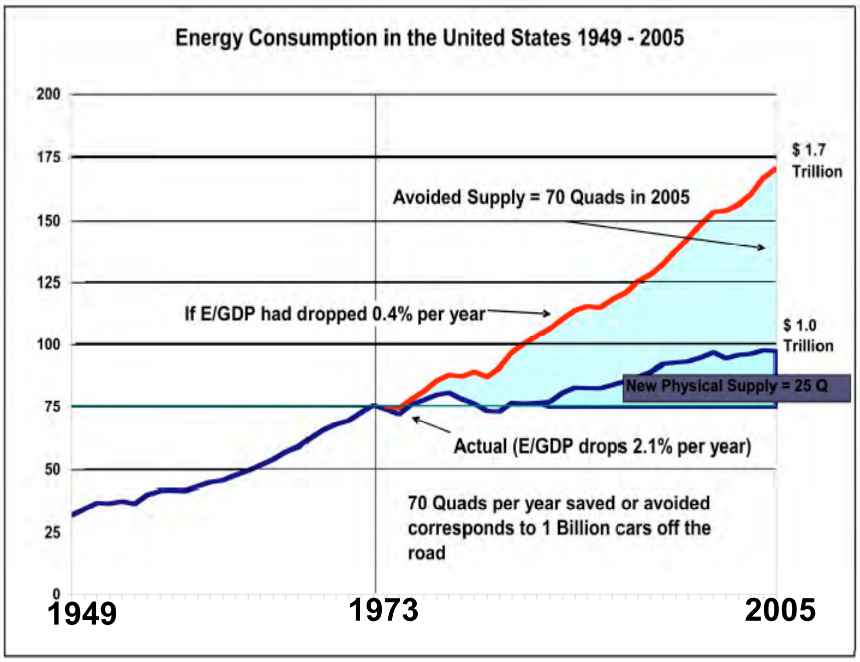

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FIGURE 2. US energy consumption in quads per year from 1949 to 1974 oil embargo to 2005. The monetary savings associated with improvements in energy intensity in the United States amount to about $700 billion in 2005 as a result of reducing primary energy.

Next we address a comparison between California (34 million people) and the US (300 million people, including California). But figures 1 and 2 included transportation fuel, which in turn depends on US Federal policies and standards, which "pre-empt" California from adopting more stringent standards. Hence, we focus on electricity where California controls its own destiny.

Annual use of electricity in kWh per person from 1960 to 2005 with forecasts through 2008 in California and in the US is illustrated in Figure 3. Use in California is currently about 40 percent less than in the US as a whole, even though use was nearly the same in the 1960s. The lines start to diverge in the mid-1970s when the US experienced its first energy crisis. At times, petroleum was rationed and energy prices increased rapidly. For example, the price of electricity to residential customers in California and throughout the US nearly doubled (in nominal dollars) from the early 1970s to the later 1970s. In addition, in the late–1970s California began its building and appliance efficiency standards, which contributed to keeping per capita electricity use in California nearly flat since 1975. Of course, compared to the entire US, other factors such as a different mix of industries and differences in climate contribute.[i] Although not depicted on this slide, other policies also have led to electricity savings in California. For example, California standards allow electric water heating in homes only when it is cost effective: which is seldom the case. This has resulted in only limited electricity use for this purpose in California.

Thus, for a variety of reasons -- some policy and others due to climate or economic variables, electricity use per capita has been flat in California and should decrease slightly as California expands programs aimed at efficiency improvements.

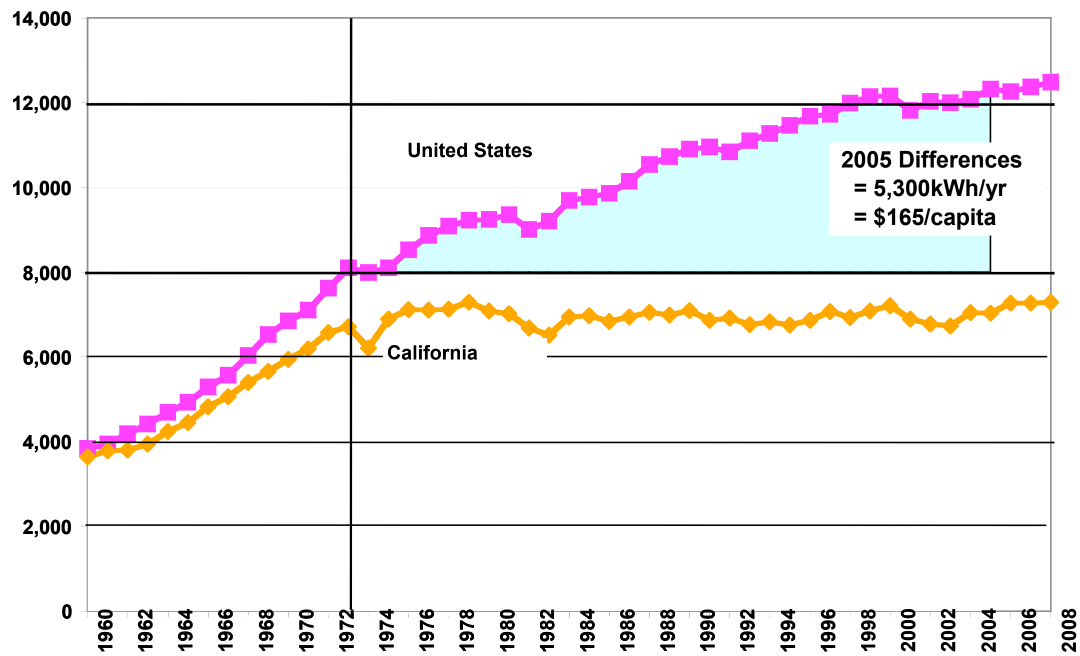

FIGURE 3. Per Capita Electricity Consumption in the United States and California.

Energy Efficient Appliances

In combination with technological improvement due to "naturally occurring" innovation, California beginning in the late 1970s introduced efficiency standards for some new appliances and buildings. In Figure 4, we provide examples of three appliance standards that were initially formulated by the state and later became US federal standards on gas furnaces, central air conditioning, and refrigerators. The trends are similar for all three but the magnitude of improvement in efficiency differs.

The amount of energy consumed in a year by the average new appliance sold in California from 1972 to 2006 (estimated) is illustrated in Figure 4. For each appliance, use is indexed to the year 1972, i.e., scaled to a value of 100. Arrows indicate when new standards took effect or will take effect. White arrows indicate state standards, which were first put in place in 1976 in response to the first oil crisis and generally rising fuel costs. US federal government standards are shown as black arrows. These did not begin until the early 1990s.

Energy use intensity by new appliances was greatly reduced by the early 2000s:

- Energy use by new gas furnaces declined by 25 percent (100% –> 75%)
- Energy use by new central air conditioners went down by 50 percent
- Refrigerators have shown the most improvement, with more than a 75% reduction in energy use.

Theses are just three examples. Many other appliances as well as building characteristics, such as insulation and windows, are regulated and these regulations are upgraded every few years as technological advancements continue to improve appliance efficiency.[ii] During development of these new regulations, industry representatives play an active and important role.

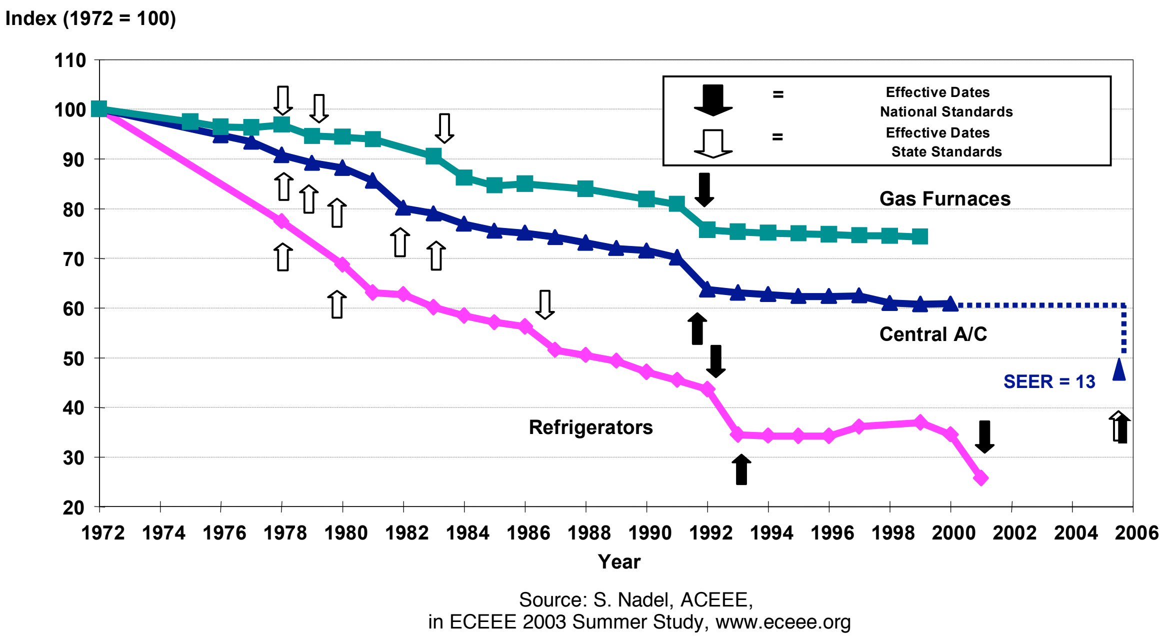

FIGURE 4. The impact of efficiency standards for three appliances (1972–2006).

The most effective path toward energy efficiency has been to set standards for autos, buildings, appliances, equipment, etc. Figure 5 shows the remarkable gains in refrigerators. The smoothly rising curve shows that the average refrigerator has increased in size. Despite that size increase, and despite the elimination of chlorofluorocarbon use, the unit energy use has decreased dramatically since 1975. Beginning in that year, refrigeration labels and standards have improved efficiency 5 % per year for 25 straight years. In the US, improvements in refrigerators has saved enough energy to avoid the construction of 40, 1-GW power plants,. Through all of this, the price for refrigerators has declined when viewed in constant dollars even as both energy efficiency and size have improved.

Continuing with the impressive gains in refrigerator efficiency, we now compare the quantity of energy saved due to these improvements with various sources of electrical generation in the US. The refrigerator data assume that all refrigerators in use meet the current standard (which of course they do not yet, but eventually will as old units are replaced with new units). In Figure 6, the comparison is based on electricity saved or generated compared to the case in which the refrigerator efficiency was frozen at 1976 levels. Using this as a basis of comparison, refrigerators save about one-third of the amount of energy that the entire nuclear fleet in the United States generates. The data are for the year 2005.

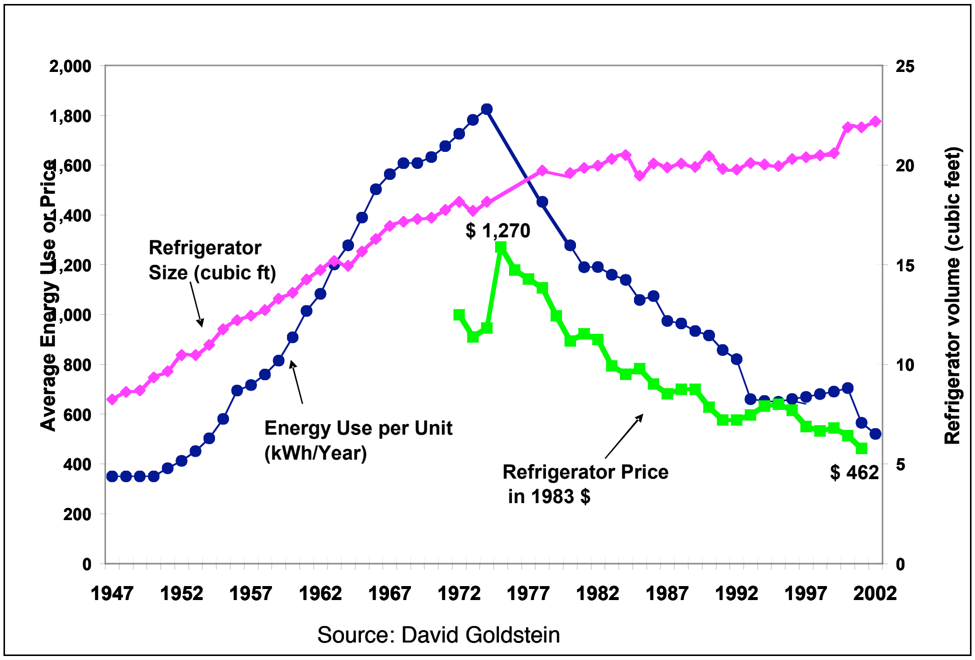

FIGURE 5. New US Refrigerators: Electricity use (kWh/year), size (cubic feet), and price (1983$).

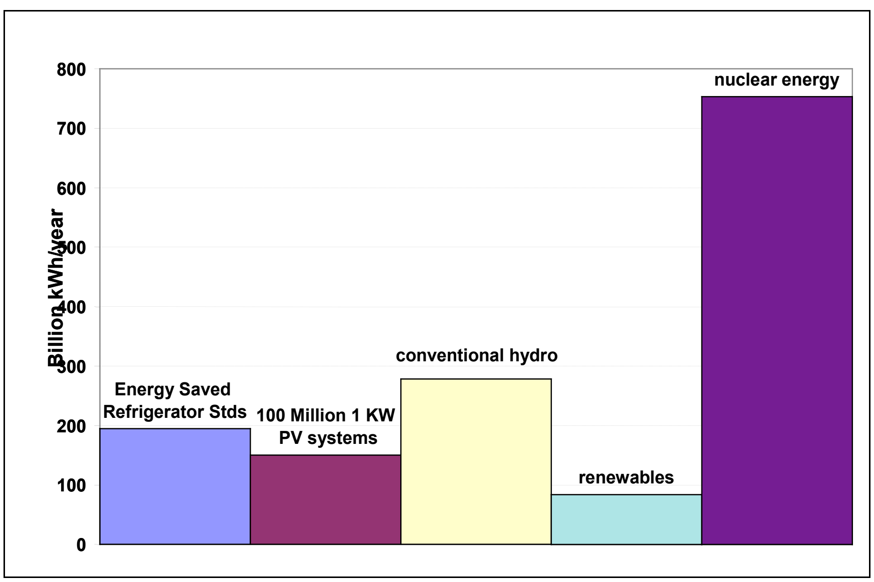

FIGURE 6. Annual US energy saved in billions of kWh/year from refrigerators vs. several sources of generation, 2005.

In the next image, Figure 7 presents a similar comparison to that in Figure 6, but here we value the electricity at the wholesale price (3 cents/kWh) for conventional hydro, renewables, and nuclear) and at the retail price (8.5 cents/kWh) for energy saved and photovoltaic systems. Using the value of the power as the metric, energy saved due to refrigerator standards has a value of nearly twice all the hydropower in the United States and about 75 percent of all electricity generated by the United States nuclear power stations. Again, we assume all refrigerators operate at the current standards for efficiency.

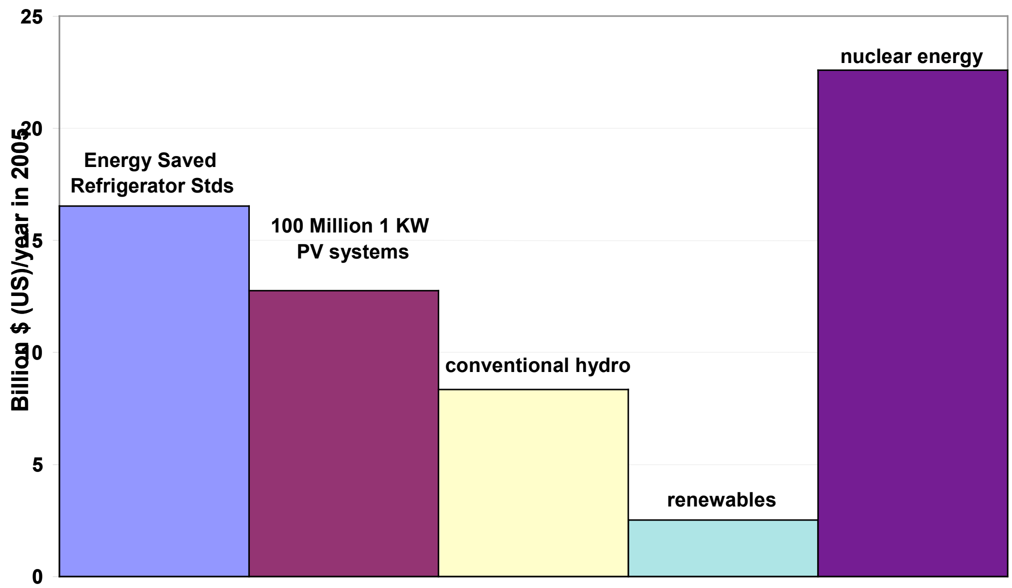

FIGURE 7. The value (billions of 2005 dollars) of electricity saved versus electricity produced in the US in 2005.

Of course, energy efficiency is not limited to the US. In Figure 8, we compare the energy production from the Three Gorges Dam in China to various efficiency standards. Figure 8 is divided into two parts:

- On the left is electricity generation from Three Gorges Dam compared to savings from China standards for refrigerators and air conditioners;
- On the right is a comparison of the dollar value of the electricity generated at the Three Gorges Dam to that of the electricity saved due to the efficiency standards illustrated on the left.

Figure 8 shows the energy saved due to efficiency standards put into effect in 2000 and in 2005 as well as the additional energy that could have been saved if the 2005 standards adopted in China had been equivalent to the current Energy Star standards in the US. Generation or savings depicted on the left side are in TWh/year, with expected generation of 100 TWh/year from the Three Gorges Dam and savings totaling nearly

90 TWh/year. These savings are calculated 10 years after the standards take effect to account for time for consumer to buy and install this equipment.

On the right side of the figure -- The value of generation from Three Gorges was calculated using wholesale electricity prices of 3.6 cents/kWh while the value of electricity saved through the standards was priced at the average cost to the consumer at 7.2 cents/kWh. The value of electricity saved is almost twice the value of that produced at Three Gorges, a somewhat startling discovery given the cost of Three Gorges versus the cost of the standards and the incremental cost of more efficient refrigerators and air conditioners.

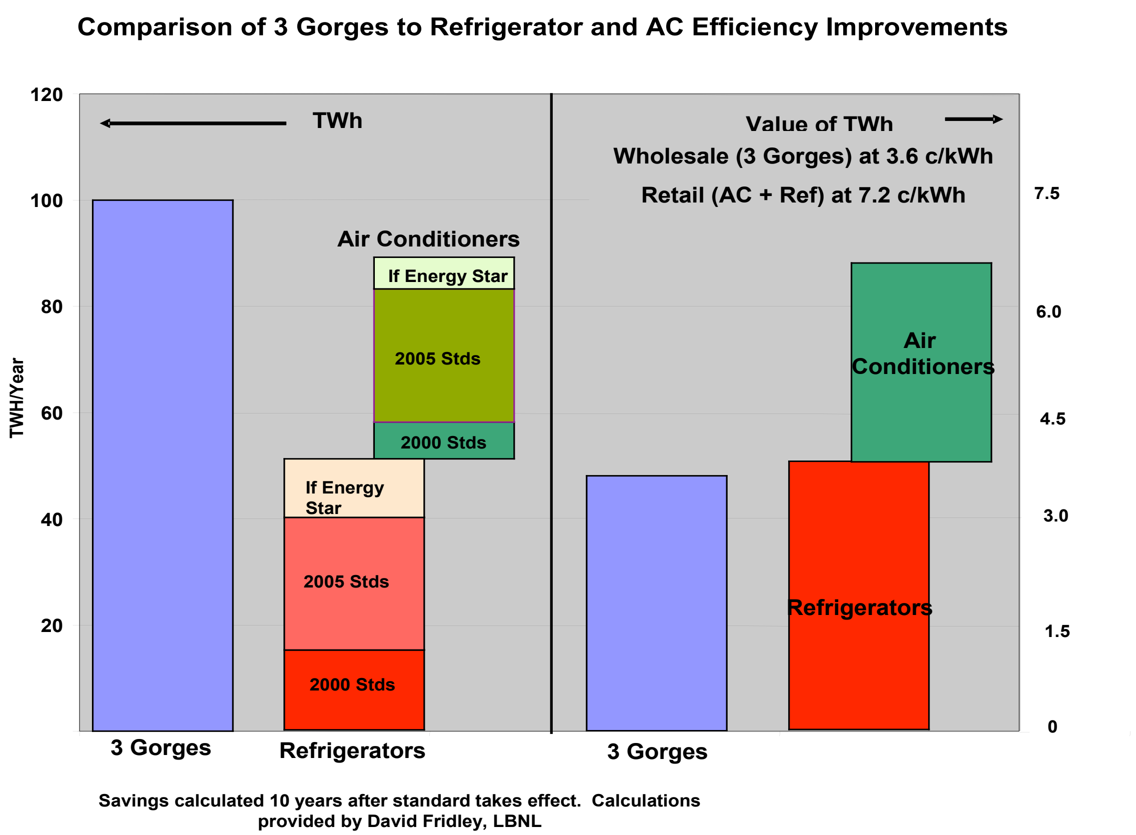

FIGURE 8. Electricity generation (TWh/year, left-hand panel) and cost of electricity (cents/kWh, right-hand panel) of the Three Gorges Dam in China compared to energy savings brought about by efficiency gains in refrigerators and air conditioners.

EFFICIENCY PROGRAMS AND STANDARDS

California's efforts to encourage efficiency through building and appliance standards provide an interesting example that is directly applicable to the issue of reducing greenhouse gas emissions. In the mid-1970s, in response to a rise in fuel prices, occasional limitations in fuel supply, concerns regarding environmental impacts of electricity production and other factors, California began to set building and appliance standards, and initiated utility programs aimed at reducing electricity use. We estimate that the current impact of these programs reduces electricity demand in California by about 40 TWh, or 15 percent. Figure 9 provides an illustration of these savings. They amount to a reduction of about 1,000 kWh per person currently.

Each year, the cost of conservation programs, public interest R&D, and standards adds about one percent to electric bills, but cuts one-half percent off the bill. So an investment of $1 in, say 1990, saves $0.50 per year for 10 to 20 years. The simple payback time is 2 years. We arrive at this by comparing the initial investment ($1) to a savings in each year of ($.50). So in two years we have paid off the initial investment, but savings continue for many more years.

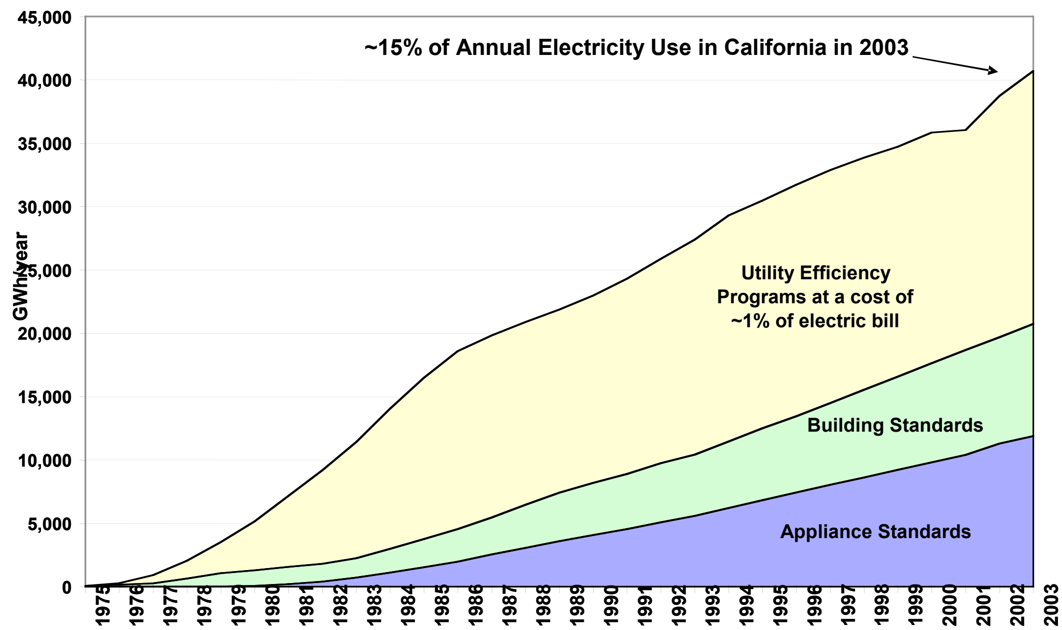

FIGURE 9. Annual Electricity Savings from Efficiency Programs and Standards in California.

However, to implement this extensive effort for utility efficiency programs, California had to put in place a number of policies. In Figure 10, we show the annual funding levels for investment in energy efficiency by California's investor-owned utilities.[iii] As the graph indicates, funding levels have fluctuated considerably since 1976. The state has now placed energy efficiency as its most preferred resource and has committed to fund these efforts aggressively for the next few years, as the figure illustrates. The figure also highlights a number of important policy decisions that the state made over this time period. These include:

- 1982 -- Decoupling utility profits from sales to eliminate the negative incentives associated with reduced sales

- 1990 -- Providing performance incentives to utilities that meet or exceed efficiency savings
- 2001 -- Including efficiency as a part of Integrated Resource Planning (IRP) and directly comparing savings to other options of meeting future load and load growth, including other policy considerations.

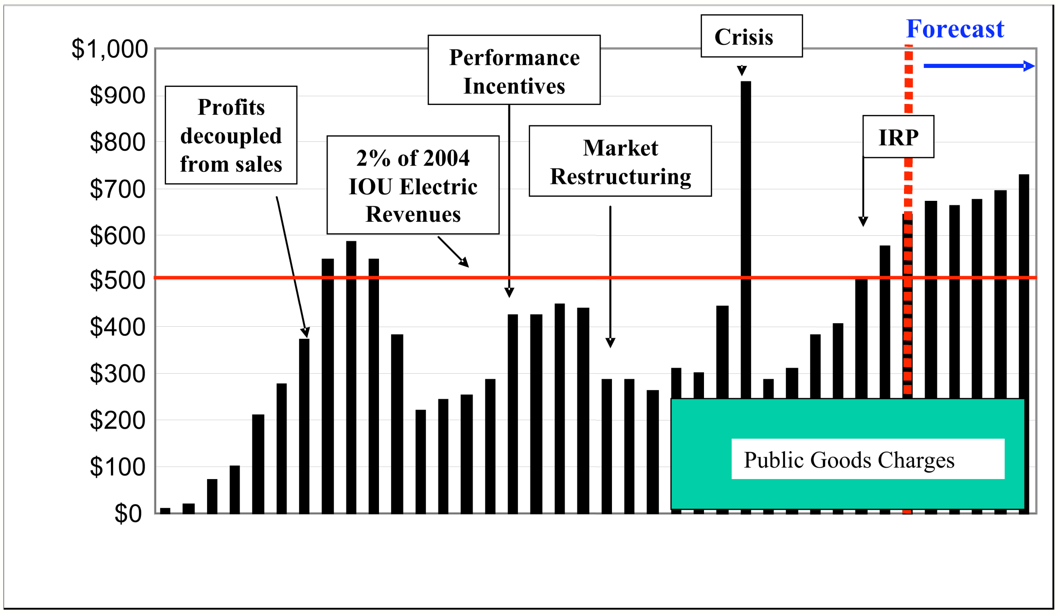

FIGURE 10. California Investor-Owned Utility Investment in Energy Efficiency. [Millions of 2002 dollars per year between 1976 and 2013]

GREENHOUSE GAS ABATEMENT

Figure 9 showed that by increasing energy efficiency in the electric sector, California currently saves about 40,000 GWh per year. We estimate that this results in an annual reduction of carbon dioxide emissions in California by 20 million metric tonnes, based on marginal generation from natural gas plants with emission rates of one-half tonne of CO_2 per MWH. California currently produces about 500 million metric tonnes of CO_2 per year.

Various estimates of the costs and methods to reduce greenhouse gas emissions are currently under discussion. Concerns abound regarding how costly it may be to reduce CO_2 emissions to acceptable levels to reduce the impact of global warming. In Figure 11, we reproduce a copy of a cost curve for greenhouse gas reductions, or abatements, prepared by McKinsey & Company (Per-Anders Enkvist, Tomas Nauclér, and Jerker Rosander[iv]) in collaboration with the Swedish utility Valtenfall. Note that in such plots, area is proportional to net annual euros saved (if area is below the x-axis) or expended (if above the x-axis). In more detail, the y-axis measures net cost of abatement in euros/tonne while the x-axis measures the size of the abatement in tonnes per year. The product (area) is the cost in euros per year. All data are for a single year – in this case the year is 2030. Total savings or costs per measure depend on the longevity of the measure. In Figure 11, considerable amount of emission abatement can be accomplished at a negative cost – that is, at a savings compared to business as usual practices. Most of these involve improving the efficiency of energy use:

- Increased building insulation
- Improved fuel efficiency in vehicles
- Improved air-conditioning system and water heating

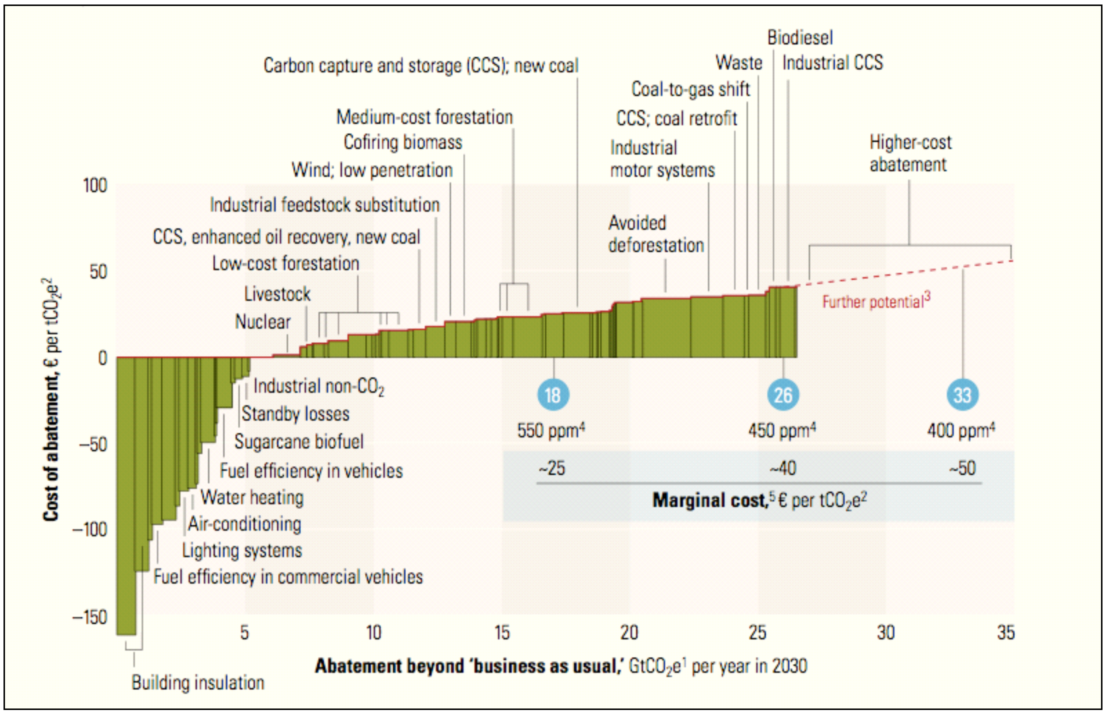

FIGURE 11. Cost Curve of Greenhouse Gas Abatement, Worldwide [McKinsey & Company].

We have estimated the area below the x-axis in this figure at ~450 Billion Euros per year, mainly from efficiency measures. Interestingly, the area above the x-axis, mainly for renewable supply, is roughly of the same magnitude. If we can implement these at savings and costs illustrated above, there would be no net cost of getting to 450 ppm of CO_2.

American readers will want to read the US study now on the McKinsey web site (http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf). Many other examples of such costs curves can be found and, generally, they show that energy efficiency measures not only reduce greenhouse gas emissions but actually save money. However, just as California had to struggle to convince others that building and appliance standards were not only a good idea but highly cost-effective, we think the same problems will arise as we try to convince others that energy efficiency is an important tool in our effort to stem the ever rising tide of global warming.

REFERENCES

[i] For a thorough discussion of these factors, see Anant Sudarshan and James Sweeney, "Deconstructing the 'Rosenfeld Curve'", Stanford University, to be published in the *Energy Journal*.

[ii] Mark Ellis, *Experience with Energy Efficiency Regulations for Electrical Equipment*, International Energy Agency, Paris, March 2007.

[iii] These utilities provide service to about 75% of the state's population. The remainder is served by municipal utilities and other public agencies.

[iv] http://www.mckinseyquarterly.com/Energy_Resources_Materials/A_cost_curve_for_greenhouse_gas_reduction_abstract